First Light from the Battery Powered Solid-State Heat-Capacity Laser for Missile Defense

Under the sponsorship of the U.S. Army's Space Missile Defense Command (SMDC), Huntsville, Ala., and in collaboration with industrial team partners, LS&T is developing a high-average-power (100-kW class), diode-pumped, Solid-State Heat-Capacity Laser (SSHCL) suitable for use as a military weapon (Figure 1). A mobile, compact, lightweight laser system capable of being deployed on a hybrid-electric vehicle is under development. Targets would include short-range rockets, guided missiles, artillery and mortar fire, and unmanned aerial vehicles (UAV).

A major step in the development of this mobile laser system is the activation of a battery-powered, diode-pumped, solid-state laser testbed at LLNL. This system utilizes lithium-ion battery-powered operation, industry-supplied diode bar assemblies, and amplifier slabs, all of which would be required to deploy a battlefield-ready system. As a proof-of-principle design, we are building and testing an SSHCL testbed using Nd:doped gallium gadolinium garnet (GGG) as the laser medium pumped by 808-nm laser diode arrays and powered by banks of batteries.

On April 3, 2003, we successfully activated the three-slab, diode-pumped, heat-capacity laser testbed (Figure 2). Twelve diode arrays provided by Decade Optical Systems, Albuquerque, N.M., were simultaneously fired into three 8-cm-square Nd:GGG amplifier slabs. Each array is assembled with 720 diode bars (nine stacks per assembly @ 80 bars per stack, totaling 8,640 diode bars). Operating at 10% duty cycle, each array has a peak output of 80 kW. Powered by the battery bank (Figure 3), we successfully generated ~0.96 MW (peak power) from the arrays. The diode arrays were pulsed at 200 Hz with a pulse length of 500 µs for 10-shot bursts and repeated for 20 burst sequences.We operated the three-slab diode-pumped testbed system at full power for a 1-s burst. Using a stable resonator with low output coupling, we obtained 50 J of pulse energy from the system.

Figure 1. Concept of a mobile, Solid-State Heat-Capacity Laser weapon.

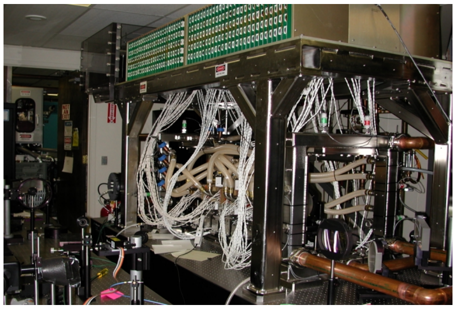

Figure 2. Three-slab diode-pumped testbed system.

Figure 3. Lithium-ion battery system.

The aperture of the laser beam is 6.5 × 6.5 cm^2. This pulse energy translates to an average power of 10 kW at a 200-Hz repetition frequency. This is the highest average power laser using battery as the power source. The optical cavity consisted of an 85% reflectivity flat output coupler and a high reflector with a 30-m radius of curvature. No attempt was made to optimize either the output reflectivity or the curvature of the reflectors. Figure 4 shows the battery-powered heat capacity laser in operation.The entire laser system is extremely compact. The diode arrays shown are roughly 15 cm long and the entire cavity is approximately 1 meter long. We performed a series of experiments to verify the performance of this new laser. Optical gain coefficient, pump uniformity, output wavefront, and temperature rise in the lasing medium were measured to benchmark our temperature-dependent energetic model. Using a full-aperture optical probe, the peak gain of the three-slab amplifier was measured to be 1.83, corresponding to a gain coefficient of 10.1%/cm.

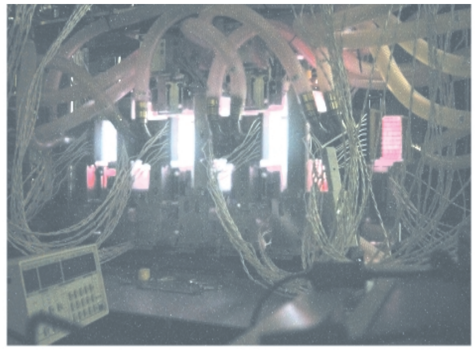

Figure 4. The three-slab SSHCL in full operation.

Using the output beam, we were able to penetrate a 9.4-mm-thick steel coupon and drill a 3.5-mm-diam hole in approximately 0.5 s. Figure 5 is a frame taken from a movie showing the laser beam penetrating the target.

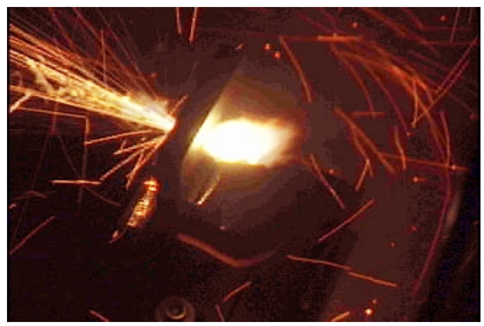

Figure 5. Laser beam penetrates a 9.4-mm-thick steel. The beam enters from the right.

Future plans for the SSHCL system include assembling and testing of the battery-powered, diode-pumped Nd:GGG testbed using additional slabs. Slab size will also be increased from the present 8-cm-square size to 10-cm square. A second lithium-ion battery set will be installed to handle the additional power requirement needs. Our ultimate goal is to develop a 100-kW laboratory device suitable for development by industry into a battlefield-ready weapon system.

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